Safety and efficacy of median sternotomy versus video-assisted thoracic surgery for lung volume reduction surgery

National Emphysema Treatment Trial Research Group*

Background: The National Emphysema Treatment Trial, a randomized trial comparing lung volume reduction surgery with medical therapy for severe emphysema, included randomized and nonrandomized comparisons of the median sternotomy and video-assisted thoracoscopic approaches for lung volume reduction surgery.

Methods: Lung volume reduction surgery was performed by median sternotomy only at 8 centers and video-assisted thoracoscopy only at 3 centers; 6 centers randomized the approach to lung volume reduction surgery. Mortality, morbidity, functional status, and costs were assessed.

Results: In the nonrandomized comparison, 359 patients received lung volume reduction surgery by median sternotomy, and 152 patients received lung volume reduction surgery by video-assisted thoracoscopy. The 90-day mortality was 5.9% for median sternotomy and 4.6% for video-assisted thoracoscopy ($P = .67$). Overall mortality was 0.08 deaths per person-year for median sternotomy and 0.10 deaths per person-year for video-assisted thoracoscopy (video-assisted thoracoscopy-median sternotomy risk ratio, 1.18; $P = .42$). Complication rates were low and not statistically different for the 2 approaches. The median hospital length of stay was longer for median sternotomy than for video-assisted thoracoscopy (10 vs 9 days; $P = .01$). By 30 days after surgery, 70.5% of median sternotomy patients and 80.9% of video-assisted thoracoscopy patients were living independently ($P = .02$). Functional outcomes were similar for median sternotomy and video-assisted thoracoscopy at 12 and 24 months. Costs for the operation and the associated hospital stay and costs in the 6 months after surgery were both less for video-assisted thoracoscopy than for median sternotomy ($P < .01$ in both cases). Similar results were noted for the randomized comparison.

Conclusions: Morbidity and mortality were comparable after lung volume reduction surgery by video-assisted thoracoscopy or median sternotomy, as were functional results. The video-assisted thoracoscopic approach to lung volume reduction surgery allowed earlier recovery at a lower cost than median sternotomy.

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The optimal surgical approach for lung volume reduction surgery (LVRS) for advanced bilateral emphysema is unknown. Case series and early randomized trials have demonstrated the superiority of stapled over laser resection[1] and of bilateral over unilateral operations.[2] Case series support the use of either median sternotomy (MS) or video-assisted thoracoscopic (VATS) approaches.[1-8] However, there are no data that directly compare the functional outcomes or longer-term results from these 2 approaches.

The National Emphysema Treatment Trial (NETT) was designed to compare the safety, efficacy, patient selection, and cost-effectiveness of LVRS with those of medical therapy for severe emphysema.[9] Compared with medical management, LVRS produced a significant improvement in function for patients with upper lobe

emphysema and improved survival for the subset of patients with upper lobe emphysema and a low baseline exercise capacity.[10] A secondary goal of the NETT was to compare mortality, morbidity, and functional outcomes from the MS and VATS approaches to LVRS. These findings are reported in this article.

Materials and Methods

The design and methods of the NETT have been described previously[9] and are summarized below.

Trial Protocol

After completion of pulmonary rehabilitation, patients with bilateral severe emphysema judged suitable for LVRS were randomized in a 1:1 ratio to a program of continued medical therapy or medical therapy plus LVRS. Eight clinical centers performed LVRS by MS only and 3 by VATS only. Six centers performed both VATS and MS, and patients at those centers were randomized between the 2 approaches in a 1:1 ratio. Twenty-four surgeons provided LVRS in NETT. At sites that provided both approaches to LVRS, some surgeons performed both approaches. Some sites that provided only 1 type of LVRS had more than 1 NETT surgeon. Patients underwent bilateral stapled wedge resection through MS or VATS; the goal was to resect 20% to 35% of each lung, targeting the most diseased areas. Use of buttressing material was at the discretion of the surgeon. The trial protocol was approved by the institutional review board of each center, and all patients signed informed consent statements.

Outcomes

Outcomes included mortality, complications, hospital stay parameters (need for intensive care unit [ICU] care, need for mechanical ventilation, and length of stay), status at initial hospital discharge or 30 days after surgery, spirometry, exercise tolerance (assessed by cycle ergometry and distance walked in 6 minutes), quality of life, dyspnea, and costs. Respiratory disease-specific quality of life was assessed by the St George's Respiratory questionnaire,[11] with scores ranging from 0 to 100; lower scores indicate less dyspnea. General quality of life was assessed by the Quality of Well-Being Scale,[12] with scores ranging from 0 (death) to 1 (ideal). Changes in functional outcomes and quality of life were evaluated at 12 and 24 months after randomization.

Statistical Analysis

Two analyses of the MS versus VATS data are presented in this article. In the nonrandomized comparison, the pooled MS group (data from 14 centers) was compared with the pooled VATS group (data from 9 centers). In the randomized comparison, the MS and VATS groups at the 6 centers that randomized between MS and VATS were compared. In the tables that follow, data are presented for the nonrandomized comparison, and *P* values are shown for both comparisons. Baseline characteristics were compared by using 2-sample *t* tests for continuous variables and Fisher exact tests[13] for categorical variables. The proportions of patients in each treatment group who died or had complications were compared by using Fisher exact or Freeman-Halton tests,[14] depending on the number of categories. The risk ratio for death was estimated on the basis of the overall mortality in each group after a mean of 31.9 months of follow-up.[15] Mortality was measured from the date of operation. Identification of subgroups of patients with differential mortality was performed with logistic regression analyses and a set of baseline prognostic factors, as described previously.[10] Length of hospital stay was derived from Medicare claims data; the length-of-stay data include stays that ended in death in the hospital, as well as discharge from the hospital. Changes from baseline in functional outcome were grouped into 10 to 12 categories ranked in order from greatest benefit to greatest deterioration, with death the worst outcome and missing data the next worst. The distributions of categories of change were compared by using the Wilcoxon rank sum test.[13] Costs for the operation and associated hospital stay and the total costs (medical and nonmedical) for the 6 months from the date of operation were collected and valued as previously described.[16] For the 6-month analysis, mean costs were estimated with the nonparametric Kaplan-Meier sample average estimator.[17] This estimator sums monthly expected costs, where the expected costs for a month are the product of the Kaplan-Meier probability of surviving to the start of a month and the mean cost among survivors over that month. Mean costs for MS versus VATS derived from the Kaplan-Meier sample average estimator method were then compared by using 2-sample *t* tests. Median costs for each group were also derived and compared by using the Wilcoxon rank sum test. All reported *P* values are based on 2-sided tests.

Results

Study Patients

Between January 1998 and July 2002, 1218 patients were randomized in NETT (610 to medical treatment and 608 to LVRS). Interim analysis identified a subgroup of 140 patients (with a forced expiratory volume in 1 second $\leq$20% of predicted and either a homogeneous pattern of emphysema or a diffusing capacity of the lung for carbon monoxide of $\leq$20% predicted) at high risk for mortality after LVRS and with little chance of benefit from the operation.[18] Patients who met these criteria were subsequently excluded from enrollment and were excluded from this analysis. Among the remaining 538 patients randomized to LVRS, 20 patients refused an operation and 7 patients were judged unsuitable for an operation after randomization, leaving 511 patients for analysis. The operation was performed via MS in 359 patients and via VATS in 152 patients. Baseline characteristics of these 511 patients are shown in Table 1. The MS and VATS groups were similar except for a larger proportion of patients with heterogeneous emphysema in the MS group compared with the VATS group (61% vs 51%, respectively; $P = .04$; Table 1). When the analysis was restricted to the centers that randomized patients to both approaches, the MS group (77 patients) and VATS group (71 patients) were comparable on all characteristics.

LVRS Procedure

Deviations from the surgical protocol (unilateral operation or bilateral operation performed in 2 sessions) occurred in 4

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TABLE 1. Characteristics of patients at baseline* (n = 511)

Characteristic	Median sternotomy (n = 359)	VATS (n = 152)
Age at randomization (y)	67.3 ± 6.0	66.3 ± 6.7
Sex, no (%)		
Female	154 (43)	65 (43)
Male	205 (57)	87 (57)
Emphysema distribution on CT, no (%)		
Predominantly upper lobe	231 (64)	101 (66)
Predominantly non–upper lobe	128 (36)	51 (34)
Heterogeneous†	218 (61)	77 (51)
Homogeneous†	141 (39)	75 (49)
Maximal workload (W)	41.4 ± 21.5	38.2 ± 21.2
FEV_1 after BD use (% of predicted)	27.9 ± 6.6	28.6 ± 7.1
TLC after BD use (% of predicted)	127.2 ± 15.0	127.6 ± 15.3
RV after BD use (% of predicted)	212.2 ± 44.5	219.6 ± 47.7
D_LCO (% of predicted)	29.5 ± 9.2	28.4 ± 9.6
Pao_2 (mm Hg)	64.6 ± 10.3	66.6 ± 11.2
$Paco_2$ (mm Hg)	42.8 ± 5.5	42.8 ± 6.0
St George's Respiratory total score‡	52.0 ± 12.8	53.1 ± 12.6
UCSD Shortness of Breath total score§	60.5 ± 18.7	60.9 ± 17.6
Quality of Well-Being Scale average daily score‖	0.57 ± 0.11	0.59 ± 0.12

CT, Computed tomography; *BD,* bronchodilator; *FEV_1,* forced expiratory volume in 1 s; *TLC,* total lung capacity; *RV,* residual volume; *D_LCO,* diffusing capacity of lung for carbon monoxide; Pao_2, partial pressure of arterial oxygen; *$Paco_2$,* partial pressure of arterial carbon dioxide; *VATS,* video-assisted thoracoscopic surgery; *UCSD,* University of California-San Diego.

*Baseline measurements were obtained after rehabilitation and before randomization except for D_LCO, which was obtained before rehabilitation and before randomization. Plus-minus values are mean ± SD.

†Emphysema distribution was based on scores assigned subjectively to each of 3 lung zones in each lung. *P* value for homogeneity = .04.

‡The St George Respiratory Questionnaire is a 51-item questionnaire completed by the patient with regard to respiratory symptoms, in which the total score ranges from 0 to 100 and lower scores indicate fewer respiratory symptoms.

§The UCSD Shortness of Breath Questionnaire is a 24-item questionnaire completed by the patient with regard to shortness of breath, in which the total score ranges from 0 to 120 and lower scores indicate less shortness of breath.

‖The Quality of Well-Being Scale is a 77-item questionnaire completed by the patient with regard to quality of life. The average daily total score ranges from 0 to 1, and higher scores indicate better quality of life.

MS patients and 8 VATS patients because of intraoperative factors. Table 2 compares features of the LVRS procedures performed with the MS and VATS approaches. The surgeons' estimates of the percentage of lung resected by MS were greater than their estimates of the percentage of lung resected by VATS; however, the grams of lung parenchyma resected by MS and VATS were not statistically different. When the analysis was restricted to the centers that randomized patients to MS and VATS, no differences were observed in the estimates of lung resected or in the grams of tissue resected.

Mortality

There were no intraoperative deaths in either treatment group. The 30-day mortality rate was 2.8% for MS and 2.0% for VATS ($P = .76$), whereas the 90-day mortality rate was 5.9% for MS and 4.6% for VATS ($P = .67$). Similar results were observed when the analysis was restricted to the centers that randomized patients to both MS and VATS. During follow-up (mean, 31.9 months), 79 MS patients and 39 VATS patients died. The overall mortality rate was 0.08 deaths per person-year for MS patients and 0.10 deaths per person-year for VATS patients (risk ratio for death in the VATS group, 1.18; $P = .42$). No predictors of differential mortality by approach were identified.

Intraoperative Experience

There was no difference between the MS and VATS groups in mean blood loss (138.0 vs 127.4 mL, respectively; $P = .55$) or need for transfusion (3.1% vs 3.3%; $P = .99$), but the mean operating time was 21.7 minutes shorter for MS than for VATS (105.0 vs 126.7 minutes; $P < .001$). When the analysis was restricted to the centers that randomized patients to MS and VATS, the mean operating time was 8.8 minutes shorter for MS than for VATS, but the difference was not statistically significant ($P = .30$).

A total of 93.0% of the MS patients and 86.2% of the VATS patients had no intraoperative complications ($P = .02$; Table 3). Hypoxemia was the only intraoperative complication that occurred with a different frequency with MS versus VATS (0.8% vs 5.3%, respectively; $P = .004$). When the analysis was restricted to the centers that randomized to MS and VATS, there were no differences in the percentage of patients without complications or in the rates of specific complications.

Experience During the 30 Days After LVRS

The only statistically different postoperative complication was the need to reoperate for air leak (MS, 2.2%; VATS, 5.9%; $P = .05$; Table 3), but when the analysis was restricted to centers that randomized patients to both MS and VATS, there was no difference in the frequency of need to reoperate for air leak. However, in the randomized comparison, failure to wean differed between groups (7.8%, MS; 0%, VATS; $P = .03$).

Table 4 shows the assessment of air leak at the completion of LVRS, the number of days with air leak for patients who survived at least 30 days, and the percentage of patients who died within 30 days of LVRS. Although there was a higher incidence of air leak at the end of the VATS procedure than at the end of the MS procedure ($P = .01$), there was no difference between groups in the number of days with air leak ($P = .74$). Air leak on 7 or more days occurred in 46% of MS patients, versus 49% of VATS patients ($P =$

TABLE 2. Features of the LVRS procedure* (n = 511)

Variable	Nonrandomized comparison: Median sternotomy (n = 359)	Nonrandomized comparison: VATS (n = 152)	*P* value†	*P* value‡
Surgeon's estimate of amount of right lung removed (%)				
<20	0.6%	0.0%		
20-34	61.8%	78.0%		
35-49	32.0%	18.7%		
≥50	5.6%	3.3%	.003	.25
Surgeon's estimate of amount of left lung removed (%)				
<20	0.6%	0.0%		
20-34	65.0%	85.3%		
35-49	26.3%	10.7%		
≥50	8.2%	4.0%	<.001	.08
Weight of right lung resected (g)	68.0 ± 30.8	62.8 ± 51.8	.17	.18
Weight of left lung resected (g)	70.4 ± 51.8	61.7 ± 73.3	.14	.35

LVRS, Lung volume reduction surgery; *VATS,* video-assisted thoracoscopic surgery; *FEV_1,* forced expiratory volume in 1 s; *CT,* computed tomography; *D_{LCO},* diffusing capacity of lung for carbon monoxide; *NETT,* National Emphysema Treatment Trial.

*Patients with $FEV_1 \leq 20\%$ predicted and either homogeneous emphysema on CT scan or $D_{LCO} \geq 20\%$ predicted were excluded, as were patients assigned to LVRS who did not receive LVRS within NETT.

†*P* values for differences in means (*t* test) or homogeneity (Freeman-Halton test).

‡Randomized comparison of median sternatomy (n = 77) with VATS (n = 71): *P* values for differences in means (*t* test) or homogeneity (Freeman-Halton test).

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.48). When the analysis was restricted to centers that randomized patients to both MS and VATS, there was no difference between groups in the presence of air leak at closure or in the number of days with air leak.

Table 5 shows the number of days in the ICU, the number of days on ventilator support for patients who survived at least 30 days after LVRS, and the percentage of patients who died within 30 days of LVRS. Days in the ICU differed by approach ($P < .001$); patients in the MS group required more ICU days after surgery than patients in the VATS group. The difference in distributions was not statistically significant when the analysis was restricted to the centers that randomized patients to both MS and VATS. Need for mechanical ventilation in the 30 days after LVRS was similar for both groups; more than 80% of patients in each treatment group required mechanical ventilation for 1 day or less.

Hospital length of stay was available from Medicare claims for 343 MS patients and 146 VATS patients (489 patients total; 6 patients were enrolled in a Medicare+Choice plan or insured by non-Medicare insurers, and claims for the LVRS procedure could not be located for an additional 16 individuals). Length of hospital stay was analyzed whether the stay ended in hospital discharge or death. The length of hospital stay (mean ± SD) was 17 ± 19 days for MS patients versus 14 ± 9 days for VATS patients ($P = .06$). The median length of stay was 10 days for MS patients and 9 days for VATS patients ($P = .01$). When the comparison was restricted to the centers that randomized patients to both MS (75 patients) and VATS (67 patients), the length of hospital stay was 19 ± 15 days for MS patients versus 13 ± 15 days for VATS patients ($P = .02$), and the median length of stay was 15 days for MS patients and 9 days for VATS patients ($P < .001$).

Residence

By 30 days after surgery, 70.5% of MS patients and 80.9% of VATS patients were living independently ($P = .02$). When the comparison was restricted to the centers that randomized patients to MS and VATS, the difference in the percentage of patients who were living independently was greater (62.3%, MS; 87.3%, VATS; $P = .001$). By 4 months after randomization, the percentages were 87.5% and 90.8% ($P = .36$), respectively, for the nonrandomized comparison and 83.1% and 90.1% ($P = .24$), respectively, for the randomized comparison.

Functional Outcomes

Histograms of the changes from postrehabilitation baseline in exercise capacity, forced expiratory volume in 1 second percentage of predicted, 6-minute walk distance, St George's Respiratory questionnaire, and Quality of Well-Being Scale after 12 and 24 months of follow-up (measured since randomization) are shown in Figure 1. Outcomes for individual patients varied widely regardless of approach, but the distributions of change were similar for both approaches. Similar results were observed when the analysis

TABLE 3. Complications* (n = 511)

Complication	Nonrandomized comparison: Median sternotomy (n = 359)	Nonrandomized comparison: VATS (n = 152)	*P* value†	*P* value‡
Intraoperative				
None	93.0%	86.2%	.02	.80
Hypotension	0.3%	0.7%	.51	.99
Arrhythmia	1.7%	0%	.19	.99
Hypoxemia	0.8%	5.3%	.004	.25
Hypercarbia	0.8%	2.6%	.20	.99
Cardiac arrest	0.3%	0.7%	.51	—§
Uncontrolled air leak	0.8%	1.3%	.64	.62
Other	3.3%	4.6%	.46	.26
Postoperative				
None	41.6%	48.0%	.20	.10
Atrial fibrillation	2.5%	1.3%	.52	.68
Arrhythmia	21.3%	21.2%	.99	.40
Failure of early extubation	3.1%	6.0%	.14	.67
Tracheostomy	9.2%	5.9%	.29	.21
Failure to wean	6.1%	2.6%	.12	.03
Reoperation for air leak	2.2%	5.9%	.05	.99
Pulmonary embolus	0.6%	1.3%	.59	.48
Readmission to ICU	11.4%	12.5%	.76	.60
Mediastinitis	0.8%	0%	.56	—§
Sternal debridement	0.8%	0%	.56	—§
Pneumonia	20.1%	13.8%	.10	.15
Urinary retention	4.2%	2.0%	.30	.68
Epidural catheter complications	1.1%	0%	.32	.99
Sepsis	2.0%	4.0%	.22	.35
Readmission within 72 h after discharge	2.2%	3.3%	.54	.35

VATS, Video-assisted thoracoscopic surgery; *ICU,* intensive care unit; *FEV_1,* forced expiratory volume in 1 s; *CT,* computed tomography; *D_LCO,* diffusing capacity of lung for carbon monoxide; *LVRS,* lung volume reduction surgery; *NETT,* National Emphysema Treatment Trial.

*Patients with $FEV_1 \leq 20\%$ predicted and either homogeneous emphysema on CT scan or $D_LCO \leq 20\%$ predicted were excluded, as were patients assigned to LVRS who did not receive LVRS within NETT. More than 1 complication could be reported for a patient.

†*P* values for homogeneity (Fisher exact test).

‡Randomized comparison of median sternotomy (n = 77) with VATS (n = 71): *P* values for homogeneity (Fisher exact test).

§The specified complication did not occur in either treatment group under the randomized comparison.

was restricted to centers that randomized patients to both MS and VATS.

Costs

Costs were analyzed for the 489 patients for whom Medicare claims data were available (343 MS patients and 146 VATS patients) and are shown in Table 6. Mean hospital and physician costs for the LVRS admission were $8207 less for the VATS group compared with the MS group (95% confidence interval [CI] on difference, $917-$16,035; $P = .03$). Mean total costs (medical and nonmedical) during the 6 months after surgery were $10,428 lower for the VATS group (95% CI on difference, $9786-$109,062; $P = .005$). When the comparison was restricted to the centers that randomized patients to MS and VATS (75 MS patients and 67 VATS patients), mean hospital and physician costs for the LVRS admission were $7138 less for the VATS group compared with the MS group (95% CI on difference, $5900-$20,177; $P = .28$). Mean total costs during the 6 months after surgery were $6500 lower for the VATS group (95% CI on difference, $4295-$8,705; $P < .001$).

Differences Between Centers

All centers had similar percentages of patients dead by 30 days after surgery ($P = .37$) and similar percentages of patients without postoperative complications ($P = .51$).

Discussion

This is the largest direct comparison of LVRS by MS and VATS approaches, and it included a subset of patients for whom the surgical approach was randomly assigned. We found that the 2 approaches carry similar risks of 30-day, 90-day, and overall mortality; have similar complication rates; and have similar changes in exercise capacity, lung function, and general and disease-specific quality of life.

TABLE 4. Air leak at closure and in the 30 days after surgery* (n = 511)

Variable	Nonrandomized comparison			
	Median sternotomy	VATS	*P* value†	*P* value‡
Air leak at closure				
None	45.7%	34.2%		
Occasional bubble or pinhole stream	37.3%	37.5%		
Intermediate stream of bubbles with respiratory variation	14.2%	25.0%		
Large stream of nearly constant bubbles	2.8%	3.3%	.01	.08
No. of patients	359	152		
Days with air leak in the 30 d after surgery				
Alive 30 d after surgery				
0 d with air leak	10.9%	11.0%		
1-6 d with air leak	40.1%	37.9%		
7-14 d with air leak	21.5%	22.1%		
15-29 d with air leak	14.8%	12.4%		
≥30 d with air leak	9.7%	14.5%		
Dead within 30 d of surgery	3.0%	2.1%	.74	.39
No. of patients	339§	145§		

VATS, Video-assisted thoracoscopic surgery; *FEV_1,* forced expiratory volume in 1 s; *CT,* computed tomography; *D_LCO,* diffusing capacity of lung for carbon monoxide; *LVRS,* lung volume reduction surgery; *NETT,* National Emphysema Treatment Trial.

*Patients with FEV_1 ≤20% predicted and either homogeneous emphysema on CT scan or D_LCO ≤20% predicted were excluded, as were patients assigned to LVRS who did not receive LVRS within NETT.

†*P* values for homogeneity (Freeman-Halton test).

‡Randomized comparison of median sternotomy (n = 77) with VATS (n = 71): *P* values for homogeneity (Freeman-Halton test).

§Data on air leak after closure were missing for 20 median sternotomy patients and 7 VATS patients who survived 30 d after surgery.

TABLE 5. Days in ICU and days on mechanical ventilation* (n = 511)

Variable	Nonrandomized comparison			
	Median sternotomy	VATS	*P* value†	*P* value‡
Days in ICU				
Alive 30 d after LVRS				
0-1 d in ICU	43.1%	65.1%		
2 d in ICU	15.3%	6.6%		
3-29 d in ICU	36.2%	24.3%		
≥30 d in ICU	2.3%	2.0%		
Dead within 30 d of LVRS	2.8%	2.0%	<.001	.76
No. of patients	354	152		
Days on mechanical ventilation				
Alive 30 d after LVRS				
0 d on ventilator	76.2%	75.7%		
1 d on ventilator	6.4%	8.6%		
2-14 d on ventilator	6.2%	7.2%		
15-29 d on ventilator	7.6%	6.6%		
≥30 d on ventilator	0.8%	0%	.86	.64
Dead within 30 d of LVRS	2.8%	2.0%		
No. of patients	357	152		

ICU, Intensive care unit; *VATS,* video-assisted thoracoscopic surgery; *LVRS,* lung volume reduction surgery; *FEV_1,* forced expiratory volume in 1 s; *CT,* computed tomography; *D_LCO,* diffusing capacity of lung for carbon monoxide; *NETT,* National Emphysema Treatment Trial.

*Patients with FEV_1 ≤20% predicted and either homogeneous emphysema on CT scan or D_LCO ≤20% predicted were excluded, as were patients assigned to LVRS who did not receive LVRS within NETT.

†*P* values for homogeneity (Freeman-Halton test).

‡Randomized comparison of median sternotomy (n = 77) to VATS (n = 71): *P* values for homogeneity (Freeman-Halton test).

The MS approach incurred slightly longer ICU and hospital lengths of stay and greater costs.

Because LVRS is a palliative, elective procedure, one of the greatest concerns was the mortality rate for the procedure. Reported operative mortality rates were generally 3.5% to 10%, but some were as high as 19.1%.[4-8,19,20] Moreover, on the basis of data for Medicare patients who underwent LVRS between October 1995 and January 1996,

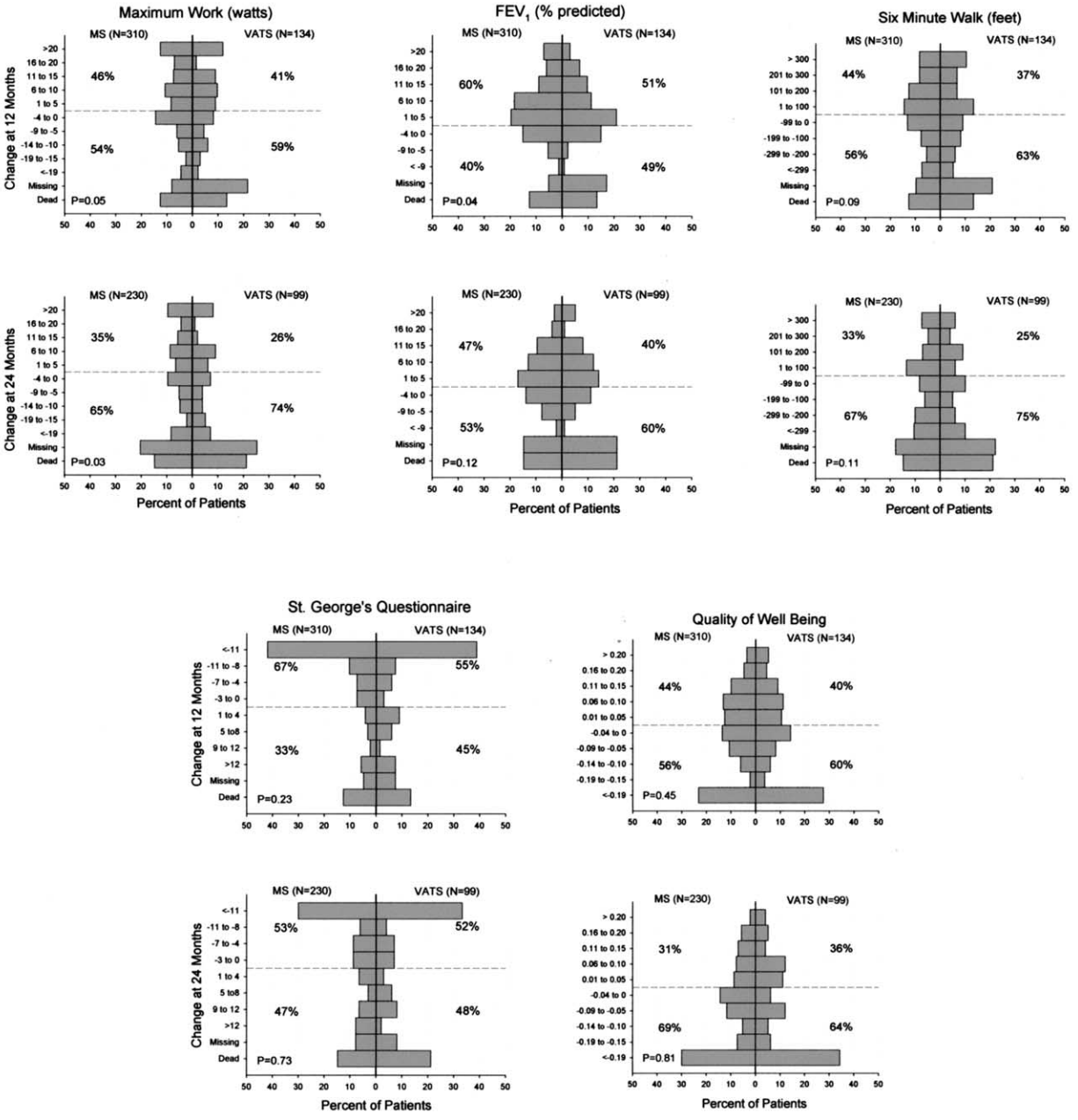

Figure 1. Histograms of changes from postrehabilitation baseline in exercise capacity (maximum work), forced expiratory volume in 1 second (*FEV_1*) percentage predicted, 6-minute walk distance, St George's Respiratory Questionnaire, and Quality of Well-Being Scale after 12 and 24 months of follow-up (measured from randomization). The category "Missing" includes patients too ill to complete the procedure and patients who refused to complete the procedure but did not provide information about why they did not complete the procedure. For the Quality of Well-Being Scale, patients who died were given a value of 0 on the questionnaire for the visit, and patients who did not complete the questionnaire were assigned a value equal to one half the lowest score observed for the visit. The *P* values for disparity in outcome distributions between the median sternotomy (*MS*) and video-assisted thoracoscopy (*VATS*) groups were determined from Wilcoxon rank sum tests; the degree to which the bars are shifted to the upper left of the chart indicates the degree of relative benefit of MS over VATS. The percentage shown in each quadrant is the percentage of patients in the specified treatment group with change in the outcome in that quadrant. Patients with FEV_1 less than or equal to 20% predicted and either homogeneous emphysema or diffusing capacity of the lung for carbon monoxide less than or equal to 20% of predicted were excluded, as were patients assigned to LVRS who did not receive LVRS within NETT.

TABLE 6. Costs* (n = 489)

Variable	Nonrandomized comparison: Median sternotomy (n = 343)	Nonrandomized comparison: VATS (n = 146)	*P* value†	*P* value‡
Cost for LVRS and associated hospital stay§				
Mean ± SD	$38,557 ± $40,519	$30,350 ± $37,219	.03	.28
Median	$23,418	$19,947		
Total costs for 6 mo after LVRS (mean ± SD)‖	$61,481 ± $3189	$51,053 ± $4502	.005	<.001

VATS, Video-assisted thoracoscopic surgery; *FEV_1,* forced expiratory volume in 1 s; *CT,* computed tomography; *D_LCO,* diffusing capacity of lung for carbon monoxide; *LVRS,* lung volume reduction surgery; *NETT,* National Emphysema Treatment Trial.

*Patients with $FEV_1 \leq 20\%$ predicted and either homogeneous emphysema on CT scan or $D_LCO \leq 20\%$ predicted were excluded, as were patients assigned to LVRS who did not receive LVRS within NETT and 22 patients for whom Medicare claims were not available.

†*P* values for differences in means (*t* test).

‡Randomized comparison of median sternotomy (n = 75) with VATS (n = 67): *P* values for differences in means (*t* test).

§Medicare reimbursements for hospitalization.

‖Includes all medical and related nonmedical costs incurred over the period.

GTS

a mortality rate of 14.4% was found at 3 months and 23% at 12 months.[21] However, in this prospective multicenter study, the NETT observed a 90-day mortality for LVRS of 5.9% for MS and 4.6% for VATS.

Postoperative morbidity after LVRS has been a source of concern. The morbidity for the MS and VATS approaches to LVRS showed very little difference. Although there was a slight trend for higher 30-day mortality after MS than after VATS, this was not statistically significant. The median hospital length of stay was longer for MS than for VATS. The rate of complications was low for both approaches and was not statistically different.

Air leak lasting 7 or more days is the most commonly reported complication after LVRS and occurs in approximately half of patients.[4-8,19,20] The NETT data for air leak are similar to published data. The VATS patients had a higher incidence of air leak at closure than the MS patients; this is presumably because intraoperative identification and elimination of air leaks is more difficult for a VATS approach than for an MS approach. However, there was no difference between the MS and VATS groups in the percentage of patients with air leak for 7 or more days.

The analysis of functional outcomes demonstrated only slight differences between MS and VATS. The VATS patients achieved independent living after LVRS slightly earlier than the MS patients ($P = .001$). However, at 12 and 24 months after randomization, the functional outcomes were essentially identical for MS and VATS.

The cost analysis demonstrated that patients who underwent VATS had significantly lower costs for the initial hospital stay. The lower costs likely reflect fewer ICU days and a reduced overall length of stay for the VATS group. Overall costs at 6 months were also lower for the VATS group.

The results of this study must be interpreted in light of the use of randomization for only a portion (29%) of the sample. Randomization was used at centers that were capable of offering and willing to offer both procedures. Some surgeons felt comfortable with either procedure, whereas at other centers, all of the procedures of a given type were performed by an individual surgeon. In any case, we think that it is important to present all of the NETT data that bear on the question of MS versus VATS. The results demonstrate the importance of randomization—a number of seemingly significant differences in the nonrandomized comparisons disappeared in the randomized subset. This is not due to the smaller sample size in the randomized comparison, because the effect size diminished or disappeared in these circumstances.

In conclusion, the data from the NETT show that complication rates do not significantly differ for the 2 procedures. Although the recovery seems to be earlier and the costs less for the VATS approach, there is no difference between the MS and VATS patients with respect to the functional results at 12 and 24 months after randomization. Patients with prior sternotomy or unilateral emphysema were excluded from the NETT. In such patients, VATS may be preferable. However, for patients without prior chest operation and with bilateral emphysema, either approach confers the same low risk of operative mortality and the same opportunity for benefits. The choice of approach is a matter of the surgeon's preference and experience.

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